STATE OF CALIFORNIA
HIGHWAY TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

A DYNAMIC FULL SCALE IMPACT TEST ON A PRECAST, REINFORCED CONCRETE MEDIAN BARRIER

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Division of Highways
Materials and Research Department

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H. W. O. 14030-951127
Project W. O. 36381

Mr. J. E. McMahon
Assistant State Highway Engineer
Bridge Department
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is a report of:

A DYNAMIC FULL SCALE IMPACT TEST ON A PRECAST, REINFORCED CONCRETE MEDIAN BARRIER SERIES XII

Study made by . . . . Structural Materials Section
Principal investigator . . . . E. F. Nordlin
Co-principal investigators . . . . J. R. Stoker and R. N. Field
Project engineer . . . . T. D. Ryan
Photographic instrumentation . . . . R. M. Souza
Report prepared by . . . . R. N. Field and R. N. Doty

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

EFN/RNF/RND:mw

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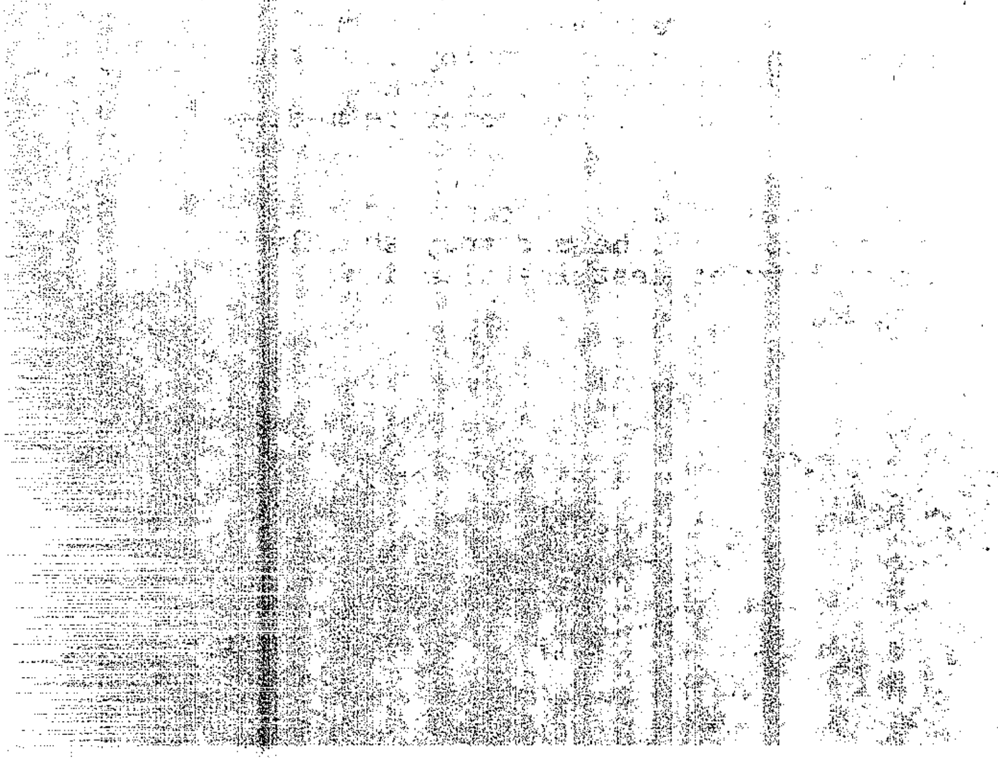
SYNOPSIS

This report presents the results of a single full scale vehicle impact test of a precast, reinforced concrete median barrier. The details of the barrier, which was designed by the Bridge Department, are shown in Exhibit No. 1 of the report.

The design tested was found to be unsatisfactory. The Bridge Department recommended that the project be discontinued with the understanding that the Materials and Research Department would undertake a series of impact tests on the New Jersey concrete median barrier design.

At the time of this writing, a contract has been awarded and construction will be underway shortly on a New Jersey concrete barrier test installation.



I. INTRODUCTION

The current California standard double blocked-out beam type median barrier has proven to be functionally effective, both during full scale dynamic impact testing and in subsequent operational service, since 1960. However, in the past several years, two factors have arisen that have indicated that other median barrier designs should be investigated.

First, increased effort is now being made to make our freeways more aesthetically pleasing to the driving public and the local community. Greater thought and attention is being given to the aesthetic treatment of bridges, retaining walls, sign structures, lighting standards, slope contours, landscaping, etc. In this respect there has been a feeling that a concrete median barrier could be designed which would be more pleasing in appearance and more compatible with its surroundings than the current galvanized steel beam and treated timber post design.

Secondly, neither the semi-rigid California standard beam type median barrier or the flexible California standard cable-type median barrier are designed for very narrow medians. The use of the cable type is now restricted to medians at least 22 feet in width due to the amount of cable deflection which can occur during high speed vehicle impact(1) and due to the need for a safe working width for maintenance repair crews. The performance of the double blocked-out beam type median barrier has been very satisfactory for median widths less than 22 feet(2) with the possible exception of very narrow medians. This barrier is 2'-6" wide and can deflect as much as 15 inches under high speed vehicle impacts. It was felt that a more rigid barrier would be more suitable for very narrow medians (less than 6 feet wide).

A concrete median barrier appeared to offer the best potential for the development of a more rigid yet aesthetically pleasing barrier. The Bridge Department was requested to develop a new reinforced concrete median barrier which would incorporate these features but which would retain the operational effectiveness of the current metal beam type barrier.

As a result, the Bridge Department proposed a series of four full scale impact tests on precast, reinforced concrete median barrier designs and a research project was approved in cooperation with the Bureau of Public Roads as Item D-4-41 in Work Program HPR-1(3), Part 2, Research. The Materials and Research Department was requested to perform the testing.

The dynamic impact test of the first Bridge Department design was conducted on October 28, 1965. This report presents the results obtained from this one full scale impact test and from preliminary static tests to develop the connector employed between the precast units.

After extensive evaluation of the photographic data accumulated during this initial test, the Bridge Department recommended that this project be discontinued with the understanding that the Materials and Research Department would undertake a series of full scale impact tests on the concrete median barrier design developed by the State of New Jersey. Preparations are now being made to test the New Jersey barrier.

This work was accomplished in cooperation with the United States Department of Commerce, Bureau of Public Roads. The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

II. OBJECTIVE

The primary objectives of this research project were to develop a concrete median barrier which would retain the functional effectiveness of the current California standard double blocked-out beam type median barrier but which would be:

1. More aesthetically pleasing.
2. More suitable for placement in very narrow medians (six feet or less).

III. CONCLUSIONS

Analysis of the data obtained from the dynamic impact test enabled the formulation of the following conclusions:

1. The barrier tested will not effectively redirect an impacting high speed vehicle.

2. Installation and particularly replacement of damaged units of this design would be considerably more difficult and costly than the current standard beam type barrier design.

IV. DISCUSSION

1. Design Tested

The median barrier tested was composed of ten precast reinforced concrete units with an over-all installation length of 79'-10" (see Exhibit 1). There was no end anchorage. The unit posts were set in drilled holes and earth compacted around them. The strength of the concrete, specified at 4000 psi, was in excess of 4500 psi at the time of the impact test. With this design the top of the beam was well above the vehicle bumper (see Plate E).

2. Test Parameters

The test barrier was impacted at an angle of 25 degrees by a radio controlled 1964 Dodge sedan traveling 66 miles per hour. The sedan with instrumentation and dummy weighed 4540 pounds. These test parameters are considered to meet the guidelines established by the Highway Research Board Committee on Guardrail and Guideposts[3].

The procedures taken to prepare, remotely control, and target the test vehicle are generally similar to those used in past test series and are detailed in a previous report[1].

3. Photographic Instrumentation

The camera and ground target placement used for this test are shown in Exhibit 2. To simplify data reduction, the elevations of the three ground mounted cameras (cameras 4, 5, and 6) were adjusted to approximate the elevation of the spheres located on top of the vehicle. For a photograph of the test site prior to the test, see Figure 1.

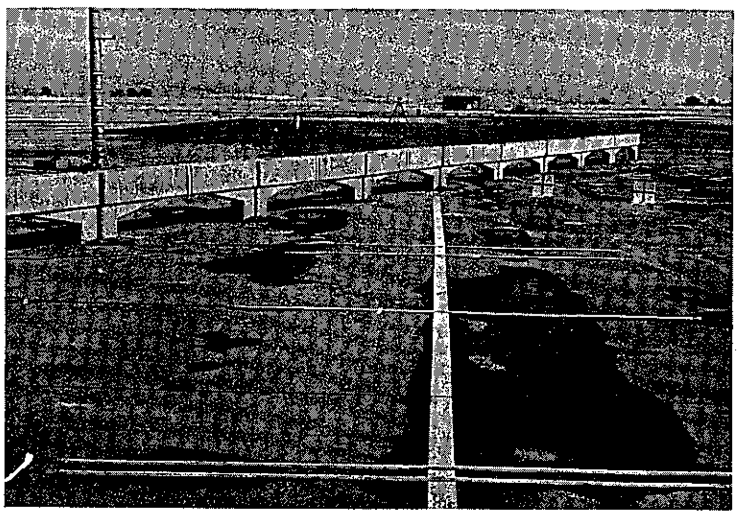


Figure 1

4. Test on Connection

Prior to the full scale dynamic test, laboratory static load tests were performed on the double-angle steel bar connection proposed for use between the units. A sketch of this connection is shown in Figure 2.

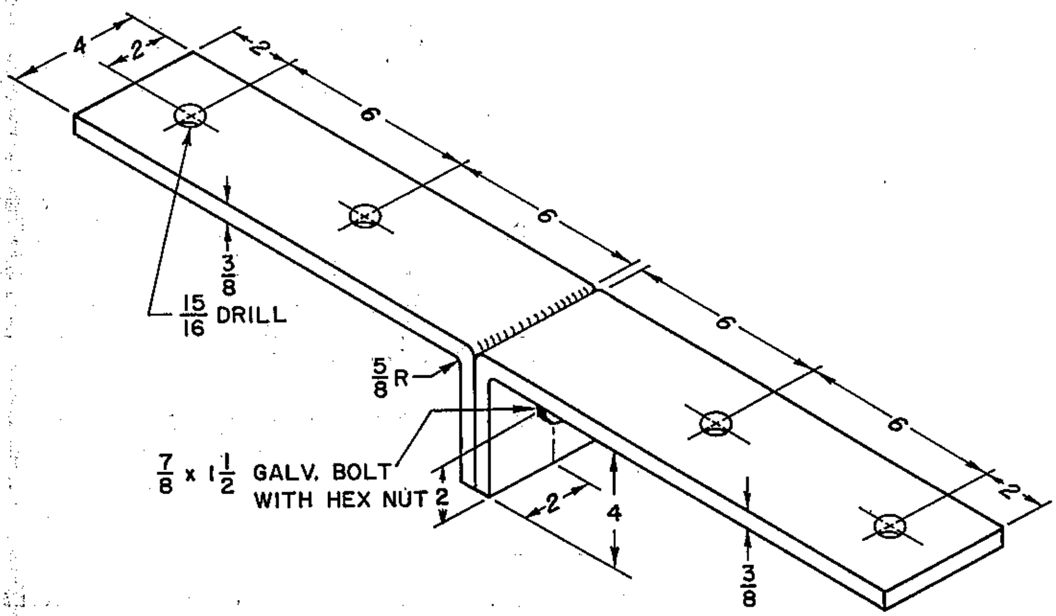


Figure 2

It was felt that for the barrier to function effectively, a minimum load transfer of 10 kips through the connection would be required. The intent of this design was to absorb a portion of the load through the deformation of the connection without excessive unit rotation and transfer the remainder to the adjacent unit. The connection shown above withstood a tensile load in excess of 14 kips without excessive yield and 27 kips before complete failure occurred. This connection was employed in the full scale dynamic test.

5. Barrier Erection

Erection of this barrier proved difficult as considerable manipulation of the barrier units was required to align the connection bolts and obtain satisfactory vertical and horizontal alignment of the entire barrier. Compaction of the backfill between the units was also difficult due to the narrow gap width (2 inches) between the posts of adjacent precast units. Special equipment would be required to replace damaged units due to their weight of approximately 1600 pounds and awkward handling characteristics (see Figure 3).

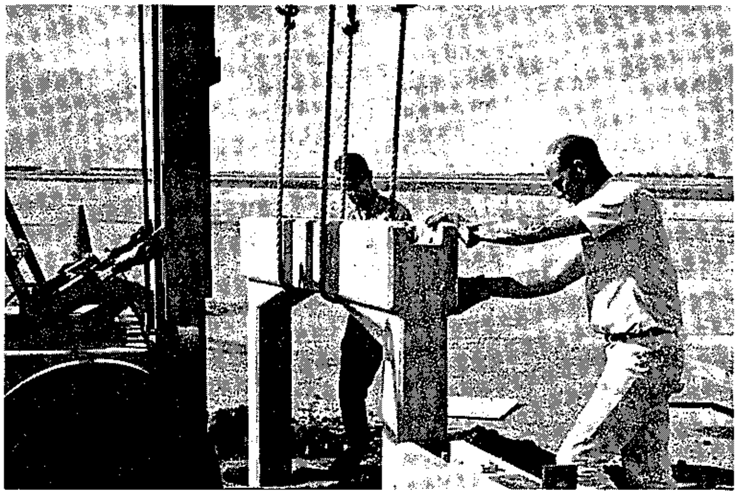


Figure 3

6. Barrier Performance

The performance of the barrier proved to be completely unsatisfactory. The lack of adequate beam strength in the 7" x 8" posts under this severe impact loading and the failure of the connection to transfer or absorb a significant part of the load permitted excessive horizontal deflection of the unit (see Plate D). The vehicle was thus permitted to penetrate across the barrier centerline and impact head-on into the exposed end of the adjacent unit, resulting in the complete demolition of its front end (see Figure 4). The impact was so severe that the engine was ejected from the vehicle, coming to rest 8 feet beyond the car. The dummy's head was thrown 23 feet from impact when the three ¼" diameter high-strength bolts in the neck joint were sheared as the shoulder struck the windshield post (see Plate E).

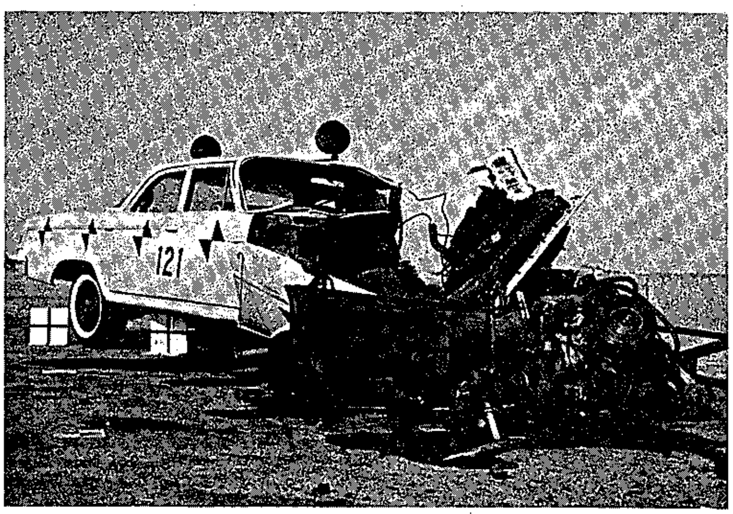


Figure 4

To effectively redirect an impacting vehicle, the deformation of the beam and post must be within the limits attainable with the material being used. The allowable deflection for concrete is relatively low due to its inability to sustain tensile stresses much in excess of 10-15% of its compressive strength. This stress can be controlled either through the construction of a larger section to increase flexural resistance or by increasing the amount of reinforcement. Either method would increase the cost and the weight of the barrier.

The posts were designed for an allowable transverse shear of 9.9 kips and an allowable transverse moment of 4.9 kip-feet. Using the ultimate theory of design, the ultimate transverse moment capacity of the post was 10.9 kip-feet. The shear capacity of the bolted double angle connection was 30 kips before bearing on the inside face of the concrete notch at the end of the unit occurred. Using an analysis based on data obtained from the films, it is estimated that the barrier sustained a moment of 100 kip-feet and a shear of 58 kips. These loads were based on an impact factor of 1.5 and did not include the shear stress on the post caused by torsion from the excessive midspan deflection in the unit 11-12 beam. This indicates that a minimum of three units would have had to act concurrently to develop adequate shear resistance. Also, five units would be required to resist the moment imposed on the barrier based on the above loads.

The test results illustrate the fact that to insure effective vehicle redirection, continuity of the barrier must be maintained. The failure of the connections at units 10-11 and 12-13 prevented successful transfer of the shear and moment loads to the adjacent units and consequently allowed posts 11 and 12 to be overloaded, resulting in excessive unit deflection both horizontally and vertically and subsequent barrier failure. Although a section of the concrete near the midspan of unit 11-12 failed completely (see Figure 5), film analysis showed that this occurred after the unit had rotated excessively in the vertical plane, thus indicating that failure of the connections and posts had already taken place.

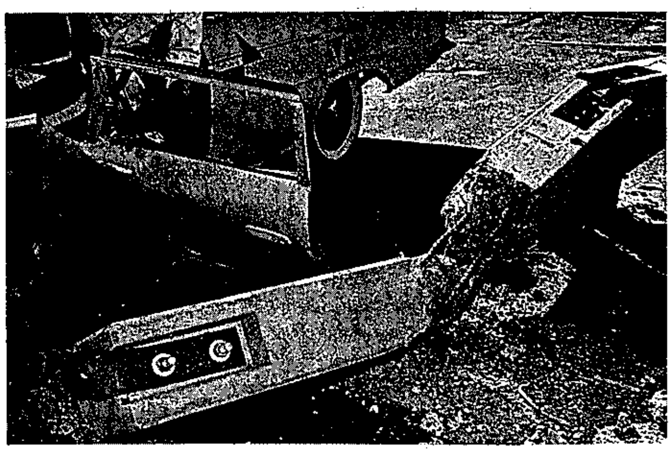


Figure 5

To insure the effectiveness of this barrier, complete load transfer to the supporting soil must be obtained. This could be accomplished either through a much larger post or a positive transfer of the load to several units. As stated above, it appears that the combined moment capacity of five units would have been sufficient to prevent the failure of this barrier.

V. TESTS

Prior to the actual full scale test of this barrier, the proposed connection between the units was tested statically to determine its load carrying and deformation characteristics. It was felt that through a controlled deformation of the connection a large portion of the energy imparted to the barrier by the impacting vehicle could be absorbed. However, the subsequent dynamic test showed that this connection should have also been designed to prevent excessive unit rotation.

The designers felt that a minimum load transfer of 10 kips would be adequate for the connection. The double angle steel bar connection used (see Figures 6 and 7) withstood a 14 kip static tensile loading without excessive deformation and 27 kips before complete failure occurred.

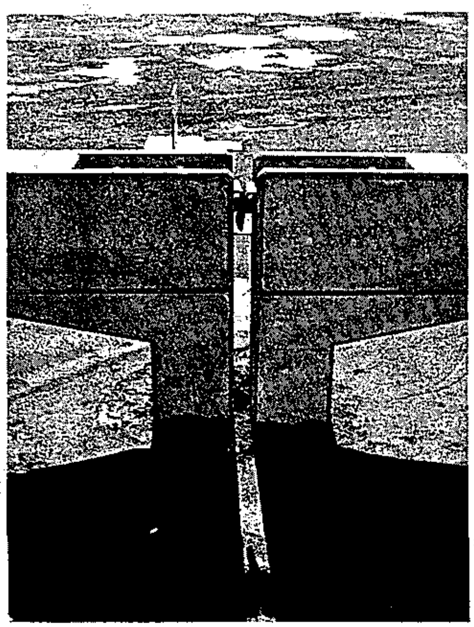


Figure 6

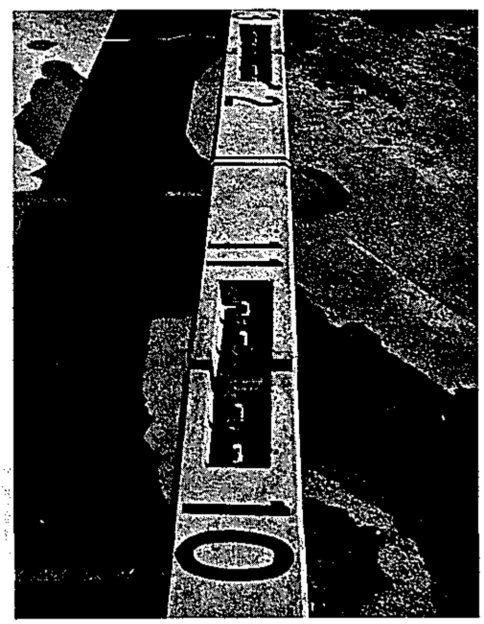
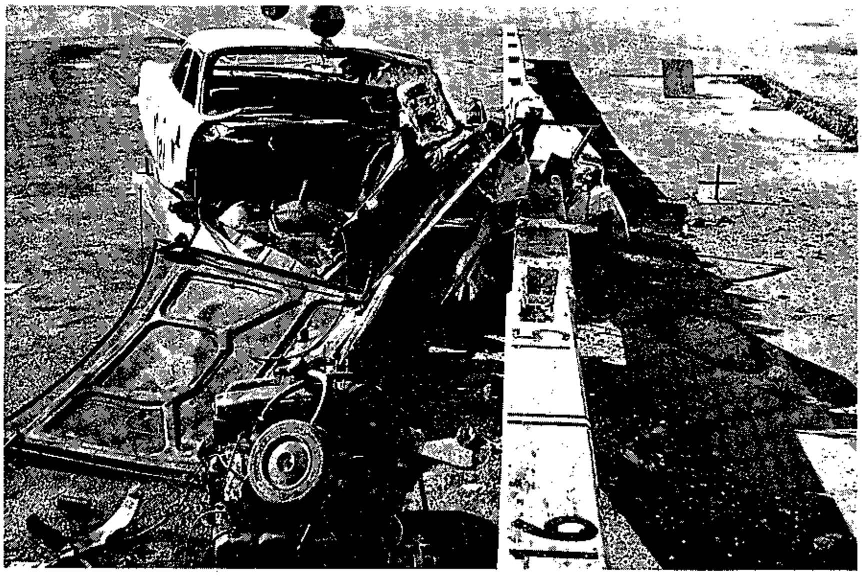


Figure 7

TEST 121 PLATE A



BARRIER: Precast, reinforced concrete median barrier. Each unit consisted of two 7" x 8" reinforced concrete posts poured monolithically with a reinforced 10" x 12" beam with the 12" face in the vertical plane. The approximate total weight of each unit was 1600 pounds. The test barrier was 79'-10" in length and was not anchored at its ends. The posts were set at a depth of 42" in compacted earth.

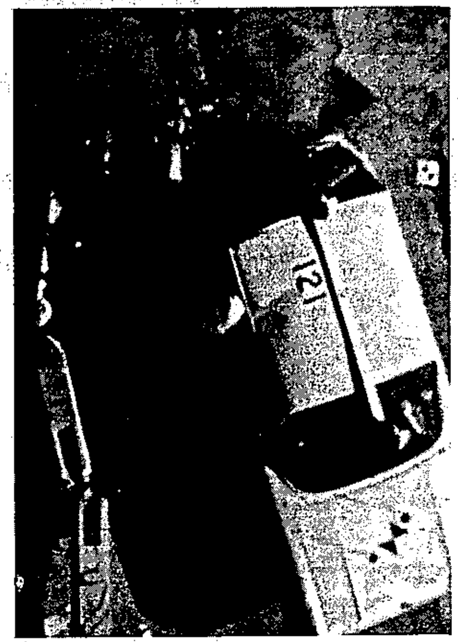
PURPOSE: To test the effectiveness of this barrier design for use in narrow medians (less than 6 ft.).

PERFORMANCE: The vehicle struck the barrier near the midspan of unit 9-10 and was partially redirected. It then penetrated under unit 11-12, lifted and broke the beam near midspan, and forced the unit to deflect back and down. The vehicle hit the end of the next unit (post 13) at an angle of approximately 10^{o} with the barrier, sustained extremely high decelerations, almost cartwheeled over the barrier, and then rotated in a counter-clockwise direction and dropped back down approximately 11 feet from impact at an angle of 25^{o} oblique with the barrier. There was no tendency for the vehicle to roll before the barrier failed. The barrier was completely ineffective in absorbing or distributing the transverse or axial forces across the unit connections.

BARRIER DAMAGE: Six of the ten units comprising the test barrier were damaged. The last two units could have been repaired using epoxy grout. The remaining four units would have required replacement, which would have been difficult where the posts were demolished at ground level.

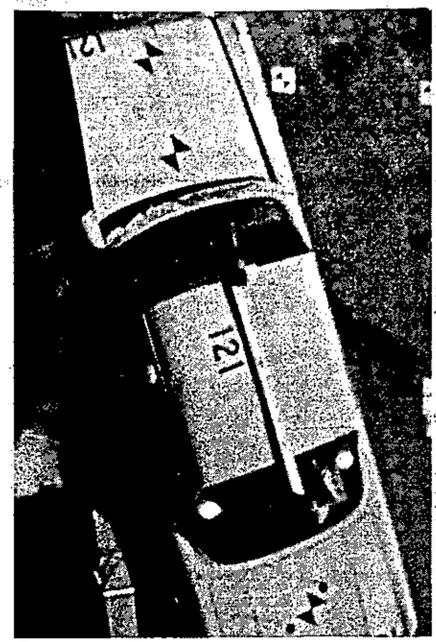
VEHICLE DAMAGE: The vehicle was a total loss.

TEST 121 PLATE B

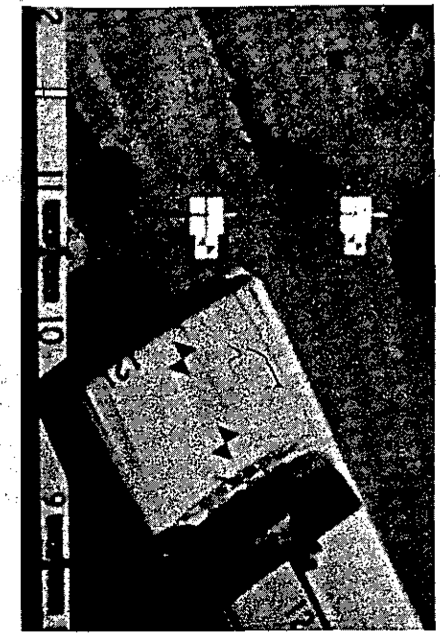


IMPACT + 3.520 Sec

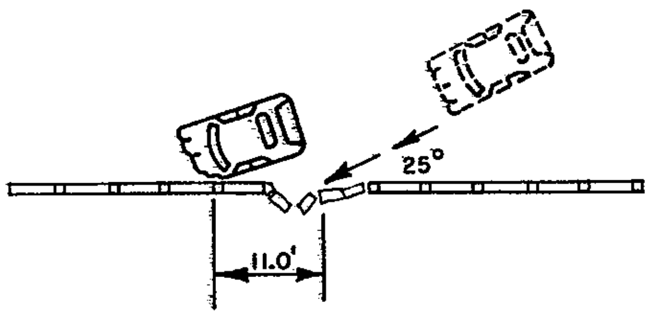
IMPACT + 1.335 Sec



IMPACT + .165 Sec

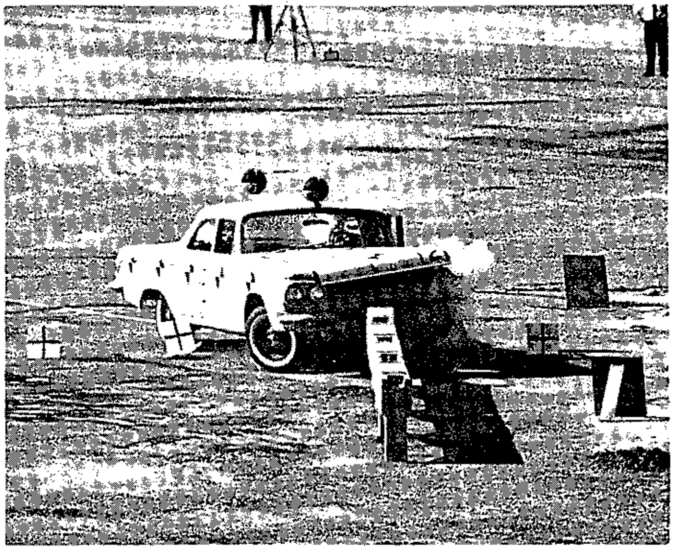


IMPACT



BARRIER	Precast, Reinforced Concrete
BEAM DIMENSIONS	10" x 12"
POST DIMENSIONS	7" x 8"
POST EMBEDMENT	42"
LENGTH OF UNIT	7'- 10"
WEIGHT OF UNIT	1600 #
LENGTH OF INSTALLATION	79'- 10"
GROUND CONDITION	Dry

TEST NO.	121
DATE	10-28-65
VEHICLE	1964 Dodge
VEHICLE WEIGHT (W/DUMMY & INSTRUMENTATION)	4540 #
IMPACT SPEED	65.9 m.p.h.
IMPACT ANGLE	25°



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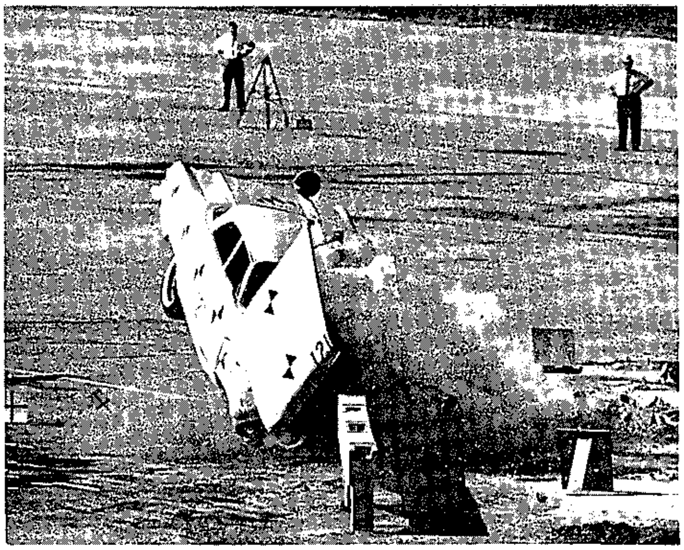

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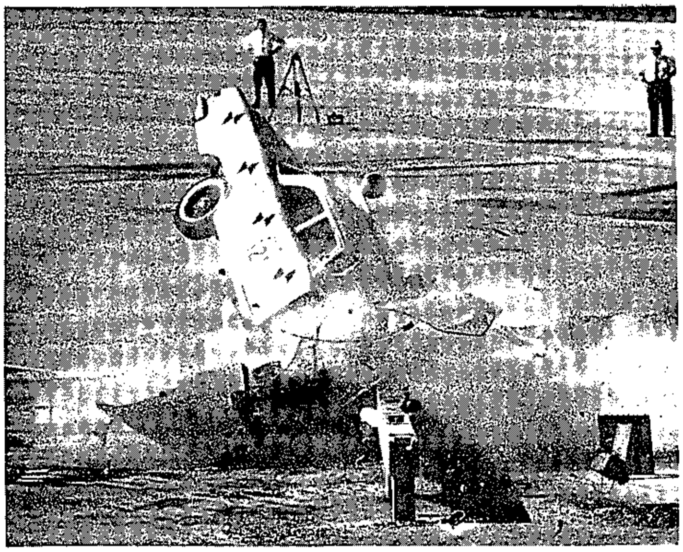
I + 0.141 Sec.



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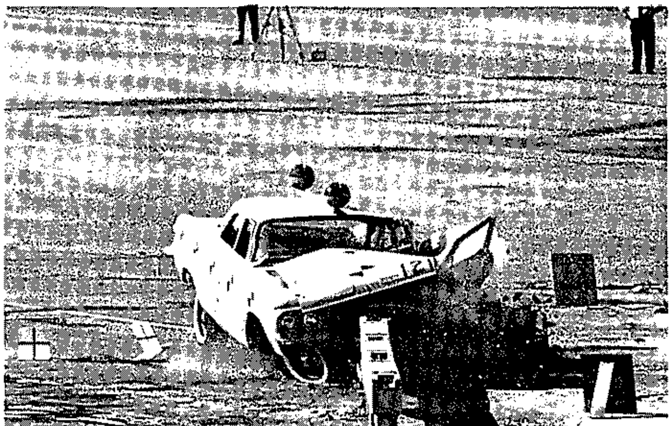
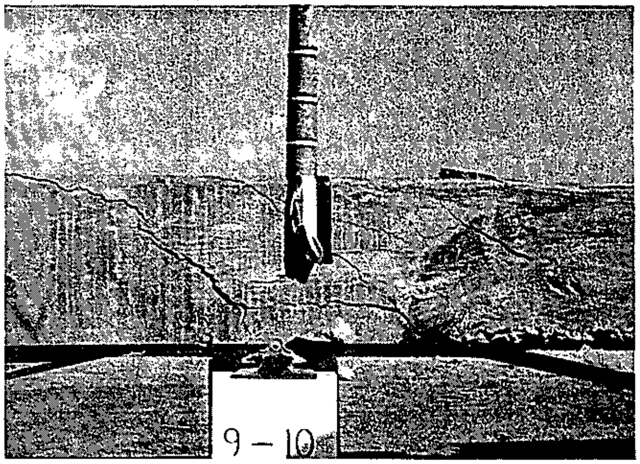
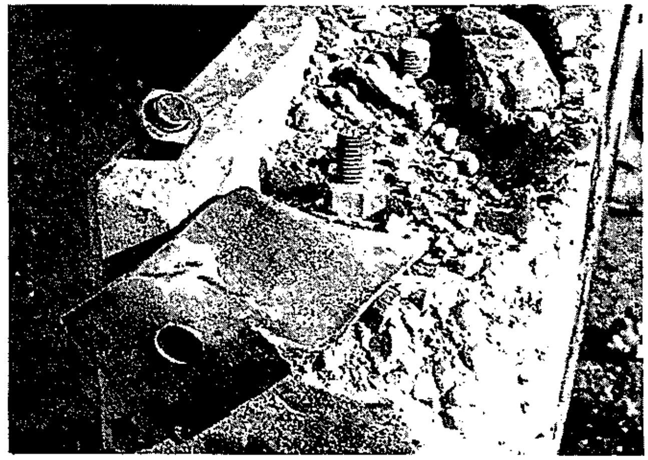



9 – 10

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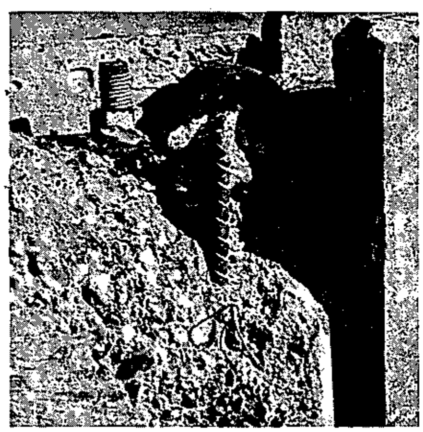
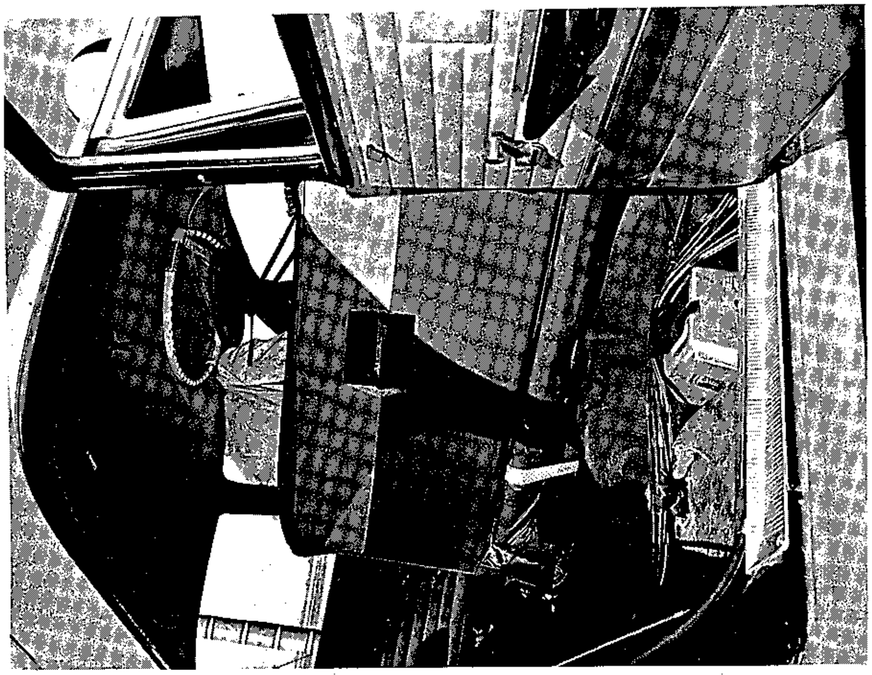
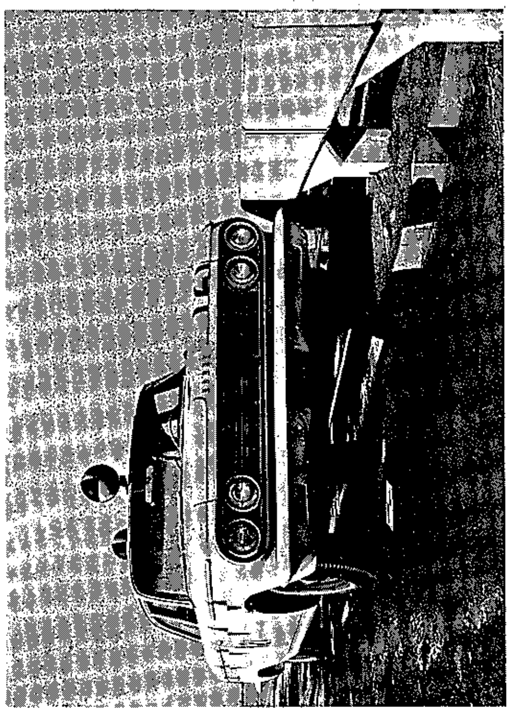




Distortion of Vehicle Interior



Bumper Height vs Beam Height

Decapitation of Dummy

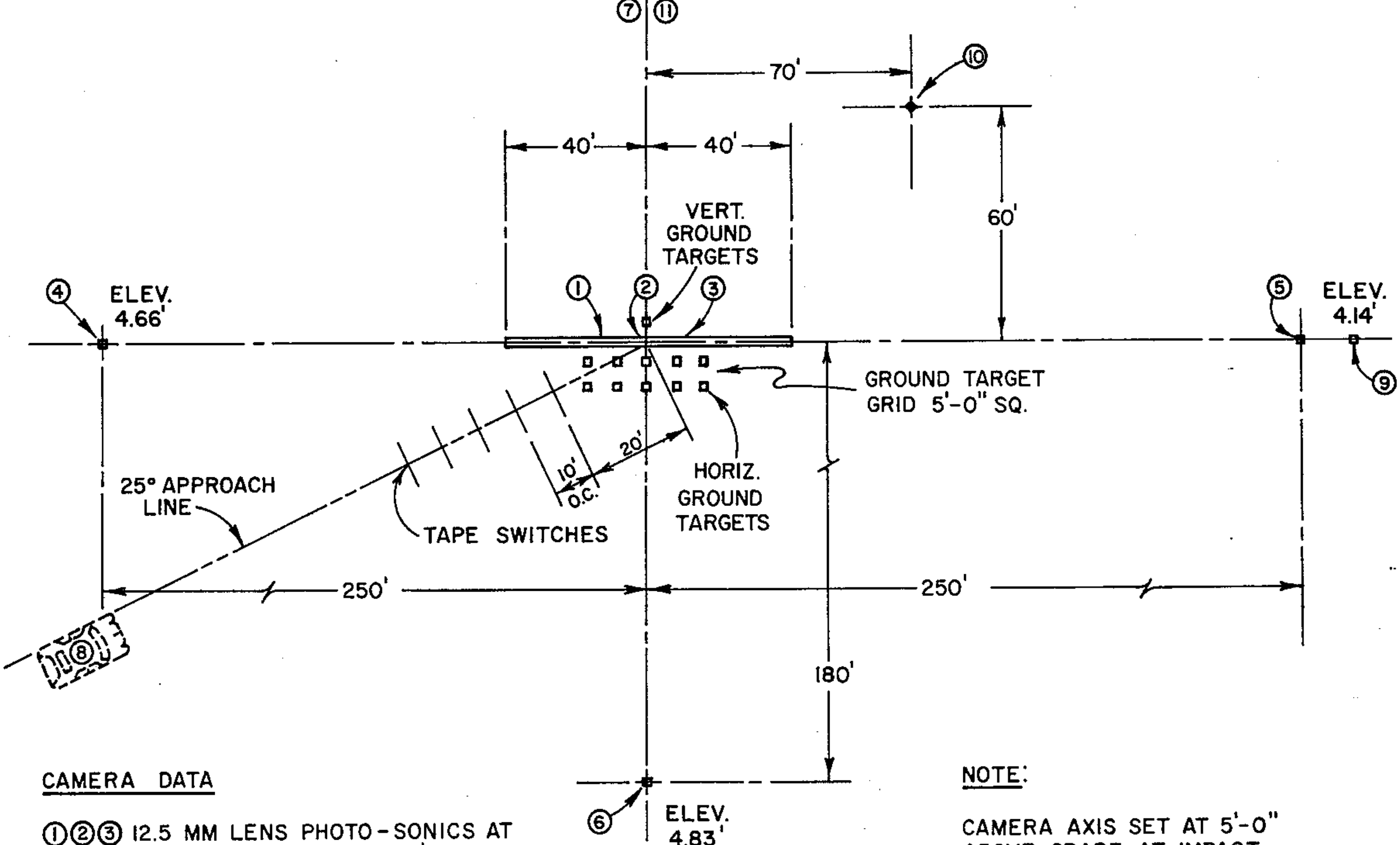
VI. REFERENCES

1. Dynamic Full Scale Impact Tests of Cable Type Median Barriers, Test Series IX, Field, R. N. and M. H. Johnson, California Division of Highways, June 1965.

2. Dynamic Full Scale Impact Tests of Double Blocked-Out Metal Beam Barriers and Metal Beam Guard Railing, Series X, Field, R. N. and R. H. Prysock, California Division of Highways, February 1965.

3. Highway Research Board Committee on Guardrails and Guide Posts, Proposed Full-Scale Testing Procedures for Guardrails, Circular 482, September 1962.

Exhibit 2



CAMERA DATA

①②③ 12.5 MM LENS PHOTO-SONICS AT 380 FPS MOUNTED ON 35' TOWER
④⑤ 4 IN. LENS PHOTO-SONICS AT 380 FPS
⑥ 2 IN. LENS PHOTO-SONICS AT 380 FPS
⑦ PAN 2 IN. LENS PHOTO-SONICS AT 380 FPS
⑧ 5.3 MM WIDE ANGLE LENS PHOTO-SONICS 200 FPS IN CAR
⑨ 14 IN. LENS 70 MM HULCHER SEQUENCE-CAMERA ON SCAFFOLD
⑩ 3 IN. LENS ROBOT 35 MM SEQUENCE AT 7 FPS
⑪ PAN 1 IN. LENS BOLEX AT 24 FPS

NOTE:

CAMERA AXIS SET AT 5'-0" ABOVE GRADE AT IMPACT.

GROUND TARGETS SET AT 90° TO BARRIER-OUT 5'-0" & 10'-0" FROM BARRIER ℄.

DYNAMIC FULL SCALE IMPACT TESTS - SERIES XII
CAMERA & GROUND TARGET LOCATIONS